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This issue contains articles on the following subjects: 1.Data Acquisition System for Motor-Vehicle Crash Avoidance Research; 2.US Army Research Laboratory: Human Research and Engineering Directorate; 3.Designing for Physical, Cognitive, and Social Attributes in Human Computer Interaction; 4.Examining the Concept of Total Fidelity Flight Simulation

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VOLUME VIII: NUMBER 2 (1997)

CSERIAC GATEWAY

PUBLISHED BY THE CREW SYSTEM ERGONOMICS INFORMATION ANALYSIS CENTER

In this issue:

CSERIAC is a United States Department of Defense Information Analysis Center administered by the Defense Technical Information Center, Ft. Belvoir, VA, technically managed by the Armstrong Laboratory Human Engineering Division, Wright-Patterson Air Force Base, OH, and operated by the University of Dayton Research Institute, Dayton, OH.

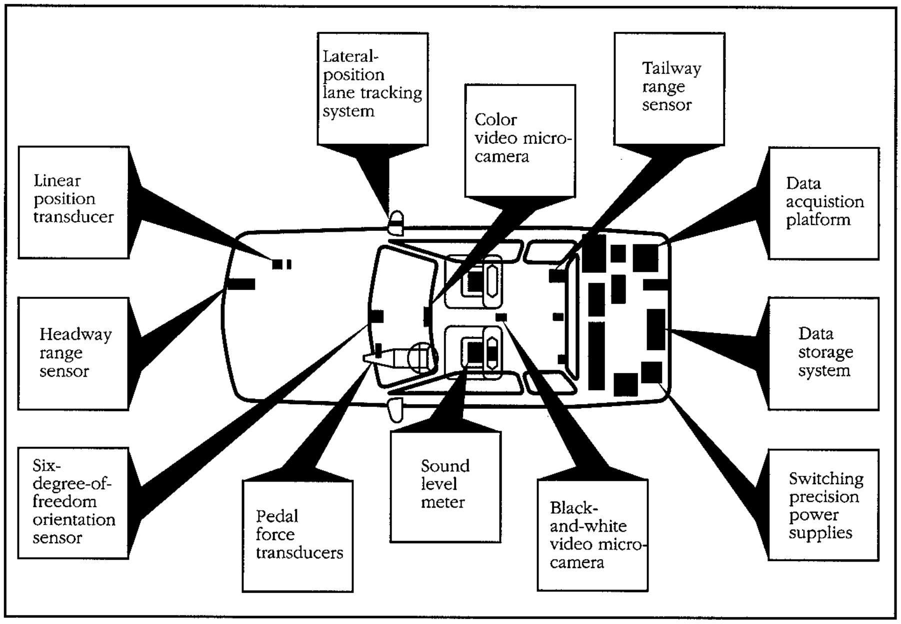

Figure 1. DASCAR provides comprehensive collection of data from vehicle, driver, and environment.

Data Acquisition System for Motor-Vehicle Crash Avoidance Research

Richard J. Carter
Frank S. Barickman
Michael J. Goodman

Given the diverse circumstances leading to motor-vehicle crashes, and the associated problem areas and issues, effective collision-avoidance countermeasures can best be realized through a comprehensive knowledge and understanding of both the events leading to crashes and the contributing behavioral, vehicular, roadway, and environmental factors. In particular, collision-avoidance countermeasures involving new and innovative technologies represent a promising use of knowledge and understanding to significantly reduce the incidence of crashes.

Effective advanced technology countermeasures, however, depend on the availability of a research tool to investigate the causes of crashes and the influence of vehicle design on the relationships among the driver, the vehicle, the roadway, and the environment. This is particularly important where advanced technology applications themselves may increase the potential for crashes or their severity under given conditions.

Continued on page 2

This research tool is vital to fully understand and document the safety benefits and potential liabilities of a wide range of countermeasures and technological advancements, and to define the requirements associated with their design and implementation. Such a capability must allow for a flexible, comprehensive, and valid appraisal of countermeasures and advanced technology applications.

The Oak Ridge National Laboratory, a US Department of Energy laboratory, recently completed a multi-year research and development program entitled "Development of a Portable Driver Performance Data Acquisition System for Human Factors Research" for the US Department of Transportation, National Highway Traffic Safety Administration (NHTSA), Office of Crash Avoidance Research. The primary objective was to develop a portable Data Acquisition System for Crash Avoidance Research (DASCAR) that will allow driver performance data to be collected on a large variety of vehicle models and types, and that could be installed on any given vehicle within a relatively short time (see Fig. 1).

Prior to the development of DASCAR, a feasibility study for designing and fabricating DASCAR was conducted with human factors and ergonomic research needs in mind. This study included a literature review of the current transportation-related human factors research to enable the identification of the parameters and measures that could be collected by DASCAR. Safety issues were evaluated to determine which tools and methods could be used to assemble, analyze, and evaluate the data collected. The measurement techniques, and state-of-the-art hardware and software for evaluating the driver/vehicle/environment were also identified. Following the development of DASCAR, it was tested and validated at NHTSA's Vehicle Research and Test Center in East Liberty, Ohio.

DASCAR is currently capable of collecting and analyzing more than 60 driver-related, vehicular and environmental parameters (see Table 1, p. 4). Driver-related variables consist of driver-control actions such as using the brake pedal and steering wheel, equipment status (e.g., hazard flashers, horn, and seat belts), and physiological measures such as the driver's core temperature, galvanic skin response, and respiration. Vehicular parameters, for example, consist of heading, pitch, roll, and yaw. While environmental parameters, such as illumination and lumination, are sensor-derived, most environmental factors are video-derived. The data acquisition system can collect other variables if a researcher so desires; this would only require additional sensors.

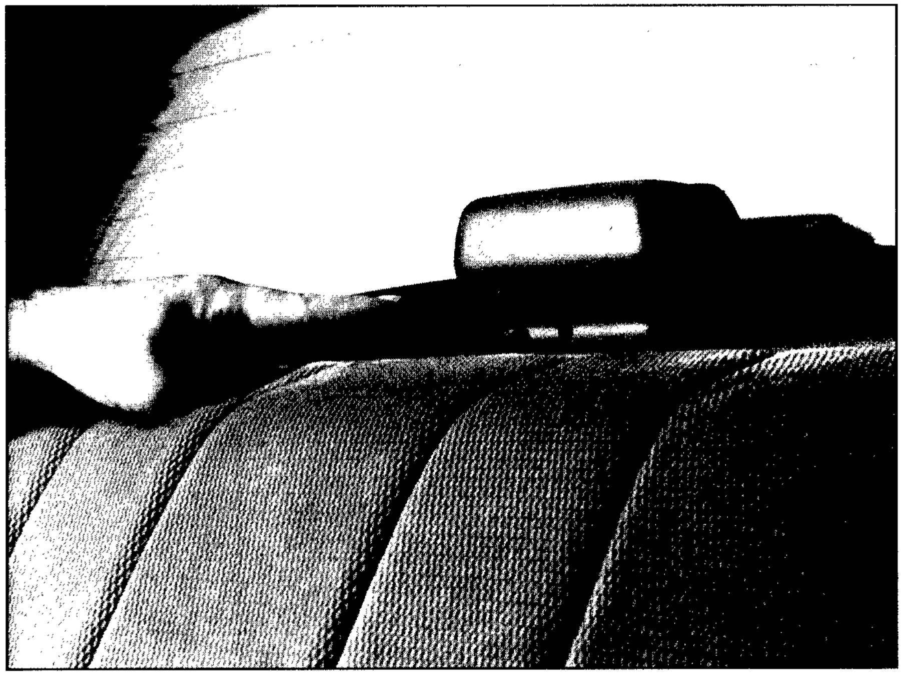

Figure 2. Micro-camera in center-mounted stop light.

The portable data acquisition system can be easily removed from one vehicle and installed in another. The complete DASCAR can be installed in an automobile or truck within one to two weeks, depending on the vehicle type and configuration. This process is not as time consuming as it may sound given the differences in structure and internal organization among different vehicle types. Taking the necessary time to find unobtrusive positions to mount each of the sensors in any given vehicle is a main goal of the DASCAR installer.

DASCAR was designed so that it can be positioned within any passenger vehicle. It can be installed within a wide range of vehicle models and types including compact, intermediate, and large automobiles and mini-vans as well as small, mid-size, and large trucks.

The data acquisition system is both unobtrusive to the driver and inconspicuous to the outside world. Placement of hardware within a vehicle does not obstruct the driver's primary task of driving. Instrumentation, cables, and wires connecting different pieces of the system are hidden, well out of the view of the driver (see Fig. 2). Antennas, sensors, and cameras are situated on the exterior of the vehicle so that they cannot be seen by other drivers. For example, micro-cameras used are very small, measuring between one and two inches, and are hidden in the rear view mirror, the dome light, and the center-mounted stop light. Similarly, the lateral position lane tracking system is hidden in the side mirror (see Fig. 3). As far as possible, the vehicle looks and drives like any other.

DASCAR was modularly designed, which permits installation of only those data collection capabilities required for a particular study. An individual does not have to instrument the vehicle with the entire system to collect or record a subset of parameters. The data acquisition system was designed with the flexibility to accommodate new data acquisition and sensor technologies as the state-of-the-art changes.

DASCAR is capable of two modes of data collection, manual and autonomous. The manual mode allows an in-vehicle experimenter to control the start and stop of the data collection through a software user's interface. The autonomous mode permits data collection to occur without an experimenter on-board. DASCAR is automatically enabled when the driver activates the ignition switch. When the driver has arrived at the desired destination and shuts down the vehicle, DASCAR senses this action, closes all its open data files, and gracefully powers off.

The data acquisition system collects parameter data over two extremes of time–from as little as 20 minutes to as much as six months.

Components

DASCAR consists of five components: a data acquisition platform and data storage system, a power system, a sensor suite, a video data system, and a central data collection/analysis facility (CDC/AF).

Data Acquisition Platform and Data Storage System

The data acquisition platform and data storage system consist of the equipment necessary to capture and process signals from the various sensors installed within and around the vehicle. The host computer which controls DASCAR is based on a single board computer currently running a Pentium processor. The data acquisition system can operate on a 486 or higher machine. Data is stored on a two-gigabyte hard drive which is mounted into a removal frame and carrier system.

Power Supply

The power supply consists of three main components: a dual-battery isolator, a sealed lead-acid storage battery, and switching precision power supplies. The dual-battery isolator provides total separation from the vehicle power system when the vehicle is powered down. This component prevents fluctuations in the vehicle charging-electrical system from entering the DASCAR power supplies when coupled with the storage battery; it serves two purposes. First, it serves a power-smoothing function, absorbing any ripples and spikes which may occur as a result of irregularities in the vehicle charging system. Second, it compensates for lowered voltages which may occur, for example, when the vehicle sits in traffic while running the air conditioning in summer heat. This battery also provides the power required for volatile memory preservation during power-down of the data acquisition system. The precision direct-current switching power supplies provide the required voltages for the various DASCAR items.

Sensor Suite

The sensor suite comprises transducers, systems, devices, sensors, and meters that gather parameter data from the driver, vehicle, and environment. A linear position transducer collects steering wheel data from the vehicle while pedal force transducers record pedal application force.

The sensor suite also includes an ambulatory data recording system composed of electronic contact sensors which collects physiological response data from the driver such as core temperature, electrocardiogram, respiration, and skin temperature (see Fig. 4). This is a one-of-a-kind system developed specifically for DASCAR. It consists of very small electrodes called fetrodes, very few of which are required to record the complete set of physiological measures. The ambulatory data recording system is very unobtrusive to the driver. No electrode paste is required and the skin does not have to be prepared prior to

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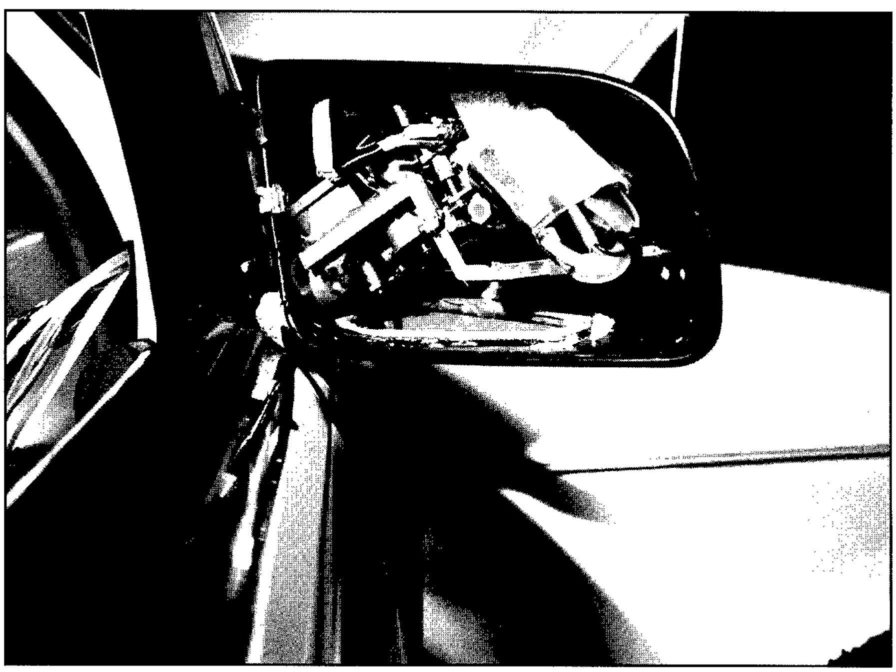

Figure 3. Lateral position lane tracking system in side mirror.

Figure 4. Custom-developed physiological recording system.

positioning the electrodes. Electrode positions are used that do not interfere with the task of driving.

The sensor suite also includes a six-degree-of-freedom orientation sensor which records acceleration (lateral, longitudinal, and vertical), pitch, roll, and yaw data from the vehicle. Other sensors include the Hall-effect sensors which collect distance traveled and velocity data, and range sensors which collect headway, tailway, target velocity, and headway time data. An electronic compass is also used to record heading data.

Ambient light data from the outside environment is also recorded as well as the sounds heard by the driver inside the vehicle. A lateral-position lane tracking system measures lateral position from the painted edge markings on the roadway and a global positioning system receiver records vehicle

Table 1. Parameters Collected by DASCAR

Driver Parameters *Driver Control Actions* Accelerator/throttle Brake pedal Steering wheel Time between accelerator release and brake application (derived) *Equipment Status* Auxiliary device (e.g., side-object detection) Brake lights Hazard flashers Headlights Horn Parking Lights Rear window defogger Rear window wiper Seat belts Turn signals Windshield wipers *Physiological Measures* Core temperature Electrocardiogram Electroencephalogram Electromyogram	Electrooculogram Fidget index Galvanic skin response Respiration Skin temperature **Vehicle Parameters** Distance traveled (derived) Elapsed time (derived) Forward velocity (derived) Heading Headway Lateral acceleration Lateral lane keeping Longitudinal acceleration Pitch Roll Tailway Time-to-collision (derived) Vehicle location Vertical acceleration Yaw **Environment Parameters** *Sensor Derived* Illumination Lumination	Noise/sound Time of day *Video Derived* Car lights Delineation Distracting lights, obstacles,and signs Exits Hand positions Haze/dust Head movements Intersections One- or two-way traffic Parked vehicles Pedestrians Posted speed limits Precipitation Road lighting Road surfaces Road types Surrounding field-of-view Traffic conditions Traffic events Traffic lights Turns/hills Lane vehicle is in

location and route traveled. The sensor suite also interfaces to the vehicle's controls, collecting the activation of various switches. Some examples of these include brake lights, hazard flashers, turn signals, and windshield wipers.

Video Data System

The video data system is composed, in part, of both color and black-and-white video micro-cameras. The micro-cameras record video data inside the vehicle such as hand positions and eye points-of-regard as well as data from the outside environment, including both the forward and rear of the vehicle.

DASCAR is capable of interfacing with two modular video data systems. Using these video data systems, video data can be recorded from up to eight cameras, all of which are time synchronized with the sensor data. These cameras can be employed to collect a 360-degree field-of-view around the vehicle, recording user interface visual and auditory warnings, and other special fields-of-view needed for specific testing.

Central Data Collection and Analysis Facility

The CDC/AF consists of components that manage, support, and analyze parameter data recorded by DASCAR. Hardware support systems include a digital, quad-picture processor, a super-VHS recorder, and a super-VHS monitor. Analysis of the acquired parameter data is facilitated by a personal computer and special supporting software, consisting of the Statistical Analysis System and the Test Planning, Analysis, and Evaluation System (PAES) developed by the US Air Force Armstrong Laboratory (now part of the US Air Force Research Laboratory). Test PAES was modified from an aircraft-oriented framework to one that will support analysis of ground transportation systems. Collection of the DASCAR sensor data at the CDC/AF is handled via a removable small computer system interface hard drive. Video data is transferred via analog tapes. The CDC/AF also contains data storage devices compatible with the DASCAR devices; these are used for archiving information and directly downloading parameter data from DASCAR.

Applications of DASCAR

DASCAR will function as the cornerstone research platform for NHTSA during the next decade, and most of their crash-avoidance research will be conducted using copies of the data acquisition system. DASCAR will be employed to collect normative driver-performance data. This will include both long-term naturalistic and traffic incident/near miss data. DASCAR will allow normative driver data to be collected within and between subjects, between various vehicle types varying in size, weight, and vehicle design features, and under a wide variety of roadway and environmental conditions such as visibility and roadway conditions. This data acquisition system will also support system-performance guideline development. This will affect guidelines regarding vision enhancements, the condition of the driver, and a variety of crash scenarios such as lane change, merging, rear-end, intersection, and roadway departure collisions. DASCAR will also be used to evaluate both conventional and intelligent transportation system (ITS) technologies. Examples of conventional technologies to be evaluated include lighting, mirrors, dashboard configuration, and control configuration. The ITS technologies consist of crash-avoidance systems (e.g., intelligent cruise control), driver navigation and traveler information systems, as well as other advanced in-vehicle systems such as active suspension and anti-lock brake systems. DASCAR will also be used to fine tune simulators and support simulator validation. ●

For more information on DASCAR, contact:

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Tel: 513-666-4511
Email:
frank.barickman@nhtsa.dot.gov

To find out about access to the technology, and present and future uses of DASCAR contact:

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Tel: 202-366-5677
Email: mgoodman@nhtsa.dot.gov

Acknowledgment

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Richard Carter is a Senior Research Staff Member with the Oak Ridge National Laboratory, Oak Ridge, TN; Frank Barickman is a Research Engineer with the Transportation Research Center, Inc., East Liberty, OH; and Michael Goodman is an Engineering Research Psychologist with the National Highway Traffic Safety Administration, Washington, DC.

GATEWAY

January 6-9, 1998
San Francisco, CA, USA
International Conference on Intelligent User Interfaces. Contact Joe Marks, Program Chair, MERL, 201 Broadway, Cambridge, MA 02139, USA. Tel: +1-617-621-7534, Fax: +1-617-621-7550, Email: marks@merl.com, WWW: http://sigart.acm.org/iui98

February 22-24, 1998
Williamsburg, VA, USA
Inter-Society Color Council Conference. Contact Wade S. Thompson, 1910 East Cardinal Street, Springfield, MO 65804, USA. Tel: +1-417-836-5110, Fax: +1-417-883-5830, Email: wst255f@nic.smsu.edu, WWW: http://www.iscc.org

February 25-28, 1998
Melbourne, Australia
International Safety Conference and Exposition. Contact Conference Organisers Pty. Ltd., PO Box 1127, Sandringham, Victoria 3191, Australia; Tel: +61-3--9521-8881, Fax: +61-3-9521-8889, Email: conforg@ozemail.com.au.

March 4-8, 1998
Melbourne, Australia
Environmental Design Research Association Annual Conference. Contract EDRA 29, EDRA Business Office, PO Box 7146, Edmond, OK 73083-7146; Tel: 405-330-4863, Fax: 405-330-4150, Email: edra@telepath.com, WWW: http://www.aecnet.com/EDRA

March 14-18, 1998
Atlanta, GA, USA
Virtual Reality Annual International Symposium, VRAIS '98. Sponsored by IEEE Computer Society Technical Committee on Computer Graphics and IEEE Neural Networks Council Virtual Reality Technical Committee. Contact Dr. Larry F. Hodges, Conference Chair, Georgia Institute of Technology, USA. Tel: +1-404-894-8787, WWW: http://www.eece.unm.edu/eece/conf/vrais

March 22-24, 1998
Dayton, OH, USA
Fourth Symposium on Human Interaction with Complex Systems (HICS). Sponsored by: IEEE/CS TC on Multimedia, US Air Force Armstrong Laboratory, Lexis-Nexis, Wright State University, and North Carolina A & T State University. Contact Dr. John M. Flach, Psychology Department, Wright State University, Dayton, OH 45435, USA. Tel: +1-937-873-2391, Fax: 937-873-3347, Email: jflach@desire.wright.edu

April 1-3, 1998
Cirencester, Gloucestershire, UK
1998 Annual Conference of the Ergonomics Society. Contact the Conference Manager, The Ergonomics Society, Devonshire House, Deveonshire Square, Loughborough, Leics LE11 3DW, United Kingdom. Tel & Fax: +44-1509-234904, WWW: http://www.ergonomics.org.uk/

April 1-4, 1998
Nottingham, UK
2nd European Conference on Cognitive Modelling (ECCM-98). Contact Frank Ritter, Psychology, University of Nottingham, Nottingham, NG7 2RD, United Kingdom. Tel: +44-115-951-5292, Fax: +44-115-951-5324, Email: frank.ritter@nottingham.ac.uk, WWW: http://www.psychology.nottingham.ac.uk/staff/ritter/eccm98/

May 3-6, 1998
Palo Alto, CA, USA
ErgoCon '98 4th Annual Silicon Valley Ergonomics Conference & Exposition. Contact Dr. Abbas Moallem, Silicon Valley Ergonomics Institute, San Jose State University, One Washington Square, San Jose, CA 95192-0180, USA. Tel: +1-408-924-4132, Fax: +1-409-924-4040, WWW: http://www-engr.sjsu.edu/ergocon/

May 17-20, 1998
Amsterdam, The Netherlands
4th World Conference on Injury Prevention and Control: Building Partnerships for Safety Promotion and Accident Prevention. Contact Conference Secretariat, Injury Prevention & Control, PO Box 1558, 6501 BN Nijmegen, The Netherlands. Tel: +31-24-323-44-71, Fax: +31-24-360-11-59, WWW: http://www.consafe.nl/conference/

May 18-20, 1998
Madison, WI, USA
Center for Human Performance in Complex Systems (CHPCS) Annual Workshop, "Expanding Human Performance Envelopes: Tools for Industry." Contact Corrine Bahr, Assistant Director, Center for Human Performance in Complex Systems, University of Wisconsin-Madison, 610 Walnut Street, Madison, WI 53705-2397, USA. Tel: +1-608-263-7456, Fax: +1- 608-263-4523, Email: chpcs@engr.wisc.edu, WWW: http://www.engr.wisc.edu/centers/chpcs

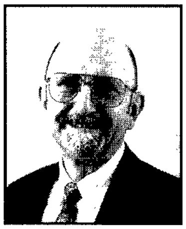
May 17-22, 1998
Anaheim, CA, USA
Annual Meeting of the Society for Information Display (SID '98). Contact Russel A. Martin, SID '98 Symposium Chair, dpiX, A New Enterprise Xerox Company, 3406 Hillview Avenue, Palo Alto, CA 94304-1345, USA. Tel: +1-415-812-9638, Fax: +1-415-812-9808, Email: ramartin@dpix.com

May 29-31, 1998
Washington, DC, USA
Fourth Conference on Naturalistic Decision Making (NDM) focusing on "Applications of NDM" and "Links to Other Research Communities." Contact Laura Militello, Klein Associates, 582 East Dayton-Yellow Springs Road, Fairborn, OH 45324-3987, USA. Tel: +1-937-873-8166, Fax: +1-937-873-8258, Email: laura@klein-inc.com, WWW: http://www.decisionmaking.com. *One-page abstracts for poster presentations may be submitted electronically to Betsy Knight until February 15, 1998, email: bknight@klein-inc.com.*

August 19-22, 1998
The Hague, Netherlands
Sixth IEA International Symposium on Organizational Design and Management (ODAM 98). Contact Peter Vink, NIA TNO BV, PO Box 75665, NL-1070 AR Amsterdam, Netherlands; Fax: +31 20 6441 450; h.knijnenburg@nia-tno.nl.

October 5-9, 1998
Chicago, IL, USA
42nd Annual Meeting of the Human Factors and Ergonomics Society. Hosted by the Chicago Metropolitan Chapter. Contact HFES, P.O. Box 1369, Santa Monica, CA 90406-1369; Tel: +1-310-394-1811, Fax: +1-310-394-2410; hfes@compuserve.com, http://hfes.org.

Notices for the calendar should be sent at least four months in advance to:
CSERIAC Gateway Calendar, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022



The CSERIAC Interface

Forthcoming Revisions of DoD Human Engineering Design Criteria Standards and Procedures Guide

Aaron "Ron" Schopper

Two of the more (if not the most) influential Department of Defense (DoD) documents affecting the application of human factors within the DoD are about to be updated—and you can contribute to the outcome.

During the next six months, CSERIAC will be formulating changes to be proposed in updating and revising the *Department of Defense Design Criteria Standard: Human Engineering* (MIL-STD-1472) and developing the coordination draft of a revised *Department of Defense Handbook: Human Engineering Program Tasks and Procedures.* (MIL-HDBK-46855A). The latter will reflect the updating and integration of two existing documents: the *Department of Defense Handbook: Human Engineering Guidelines for Military Systems, Equipment, and Facilities* (MIL-HDBK-46855) and the *Human Engineering Procedures Guide* (DOD-HDBK-763).

The Documents

Until the recent standardization reform activities focusing on the use of non-government standards, MIL-STD-1472 was *the* set of operator- and maintainer-related human engineering design criteria routinely applied to materiel acquired by the DoD. MIL-HDBK-46855 (formerly MIL-H-46855 and MIL-STD-46855, another of the venerable, key human engineering references for the DoD) was used by the services to identify the human engineering efforts to be undertaken during the acquisition of systems and equipment for the DoD.

DOD-HDBK-763 was developed to amplify and supplement the information in MIL-HDBK-46855. As a pair, MIL-HDBK-46855 and DOD-HDBK-763 were intended to guide and assist those having human-engineering-related responsibilities on both sides of the DoD acquisition fence. The information assisted those within the DoD to ensure that human engineering issues were appropriately delineated in the description of system/equipment requirements and that human engineering concerns were effectively monitored and implemented during the remainder of the development cycle (i.e., during the analysis, design, and test & evaluation phases).

In a complementary manner, related information was also provided to assist those within contractor or performing organizations who were responsible for ensuring that the human-engineering-related matters were properly addressed during product development and evaluation, and to assist those actually performing the work.

Previous Versions

The Department of Defense has long been interested in human engineering. Initially, each of the services developed and published its own general human engineering design criteria standards. However, the relative inefficiency and potential downsides of continuing to independently pursue separate standards were recognized by the DoD, and in 1968 the efforts of the services were consolidated into a single standard: MIL-STD-1472.

During the years since 1968, there have been multiple versions of MIL-STD-1472. The most recent technical update, MIL-STD-1472D, appeared in 1989. In 1996, the present version, MIL-STD-1472E, appeared. It is, in large measure, an administrative revision undertaken to accommodate concerns expressed by the Defense Standards Improvement Council. Those concerns related to its length, the documents referenced, the apparent overstepping of its stated scope, the unwarranted inclusion of handbook-like (vs. criteria) information, and the relative obsolescence of the content in some areas.

As a consequence of its review, the Council recommended that those aspects that could be quickly and effectively addressed via a predominantly editorial process be accomplished in the short term (resulting in MIL-STD-1472E), and that a technical update be later scheduled (i.e., a forthcoming 1472F). The Council also required that MIL-STD-46855, *Human Engineering Requirements for Military Systems, Equipment, and Facilities,* be converted to a handbook along with all other programmatic (or tasking) documents.

For the last five years, concerns relating to DOD-HDBK-763 were raised by US Army's Aviation and Missile Command (AMCOM), the preparing activity, regarding the need for that handbook to reflect and accommodate the substantial changes to DoD's acquisition policies, standardization reforms, human factors program initiatives, and new human engineering tools and techniques that emerged

Continued on page 8

since the publication of the initial issue, currently in use. Moreover, coverage and status of DOD-HDBK-763 and MIL-HDBK-46855 led AMCOM to conclude that these two handbooks should be consolidated into a single document. Accordingly, AMCOM has identified (and is sponsoring) CSERIAC as the organization to develop the information and provide the drafts of the materials needed to accomplish these updates and revisions.

I have had the good fortune to be selected to lead the project. Regarding MIL-STD-1472, our intent is to compare the contents of the current version, MIL-STD-1472E, with pertinent information appearing in other national and international standards (both government and non-government), recent research database material, and the general body of empirically based human engineering knowledge. Predicated on the results of that effort, we will generate extensive proposed changes and additions, each with an accompanying rationale. After a screening of this set of recommendations by the DoD Tri-Service Technical Group for MIL-STD-1472, appropriate changes will be forwarded to AMCOM for use in the preparation of a coordination draft that will be circulated for comment.

Input Requested

To bring the matter back to the point of the stick, this extensive effort will have to be completed within a relatively short time-frame. Final recommendations for proposed changes and additions are to be completed by the end of June 1998.

Given the pervasive impact of MIL-STD-1472 (i.e., its direct applicability to DoD systems and equipment and its substantial influence upon the non-DoD arena, as well, due to its considerable historic status and credibility), we would like your assistance in making the final product as sound and viable as possible. To that end I am soliciting any and all input that would be of assistance in updating MIL-STD-1472.

Experienced-based Recommendations. For those working within or for the DoD, there may exist particular instances wherein you are aware that additional criteria, now available, should be included. Have you encountered provisions you believe are out-dated? Have you searched the standard for needed design criteria and not found it, suggesting that amplification is needed or an additional topic should be included? Most important, are you aware of recently developed design criteria, accepted by the technical community, that should, but does not, appear in the standard? We anticipate that many such concerns exist as pertain to the application of new technologies during the last decade (e.g., speech interfaces).

If you have answered "yes" to any of the above questions, you can contribute to the updating effort. If you have suggestions as to potential additions or changes, we'd like to hear about them. We'd particularly appreciate it if you could provide the precise wording you believe should be used for any proposed new provisions. The rationale for your suggestion and the identification of a supporting research document or other reference would be equally appreciated.

Recent/Current Research

If you or your organization (government or non-government) has generated reports on pertinent research or a review of the literature that has only recently appeared or is not yet published, we would like to be apprised of same.

If possible (and if there is no associated cost), we would appreciate receiving a copy or reprint of the report—or at least be informed as to how a copy can be acquired. Information databases are often a year or more in arrears, and we would very much like to have the benefit of the most recent information and research findings available.

The Bottom Line

The bottom line is that we have started a large-scale effort to update, revise, and consolidate some of the DoD's most influential human-engineering-related documents. However, the quantity of pertinent information and research that has surfaced during the decade since the last technical update of MIL-STD-1472 is so large as to preclude any pretension that a 100% review of the relevant research and references can be accomplished given the resources available. The same applies to the section of DOD-HDBK-763 describing human-engineering-related tools. Accordingly, the extent and the quality of resulting updates and revisions of these documents will reflect the level and quality of effort applied to the project.

As previously stated, we are interested in learning of any data gaps you may have experienced in attempting to use any of the documents cited above, *and* we are soliciting input from you regarding the existence of research findings, literature reviews, emerging guidelines, or proposed standards that you believe would be helpful to the effort. We welcome your support! Please contact Paul Cunningham directly to express your interest or to seek additional information regarding the project; Tel: (937) 255-5215 [DSN: 785-5215], Fax: (937) 255-4823, or Email: cunningham@cpo.al.wpafb.af.mil

Aaron "Ron" Schopper, Ph.D., is currently with NIOSH, Morgantown, WV, and prepared this article as the Chief Scientific and Technical Advisor for the CSERIAC Program Office. This program, begun by Dr. Schopper, is now under the technical direction of William Moroney, Ph.D., University of Dayton, Dayton, OH.

US Army Research Laboratory Human Research and Engineering Directorate

Douglas Tyrol

In 1951 the Army recognized the need for "incorporating in the physical design of complicated mechanisms, design features which will permit the "average man" to realize the full functional potentialities of the equipment even under the most adverse operating conditions." The result was the creation of the Human Engineering Laboratory (HEL) to conduct basic and applied research with the objective of optimizing soldier performance and the soldier-machine interface. Over the next 40 years HEL grew to be nationally and internationally recognized in human performance research and human factors engineering technology development. In 1992 HEL was combined with the Systems Research Laboratory of the Army Research Institute for Behavioral and Social Sciences to become the Human Research and Engineering Directorate (HRED) of the Army Research Laboratory (ARL). This merging of prominent human factors with manpower and personnel integration (MANPRINT) organizations has served to focus, unify, and strengthen the Army's program.


Figure 1. Soldier negotiating zig-zag obstacle with anti-tank launcher.

Centered at Aberdeen Proving Ground, Maryland, HRED conducts research in the areas of soldier visual and auditory perception, soldier information processing, performance metrics for Command and Control, operator and maintainer workload modeling, and human-system design tools for front-end analysis.

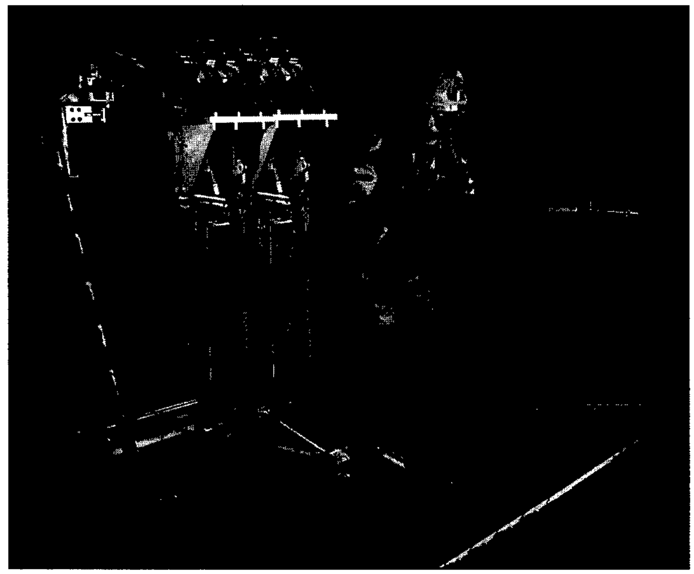


Figure 2. Individual Solder Mobility Simulator (ISMS).

In addition, HRED provides human factors and MANPRINT analysis support to combat (armor, infantry, artillery, etc.) and materiel (Missiles, Tank Automotive, Communications-Electronics, etc.) developers.

The modern facilities at Aberdeen include:

- A computerized obstacle course designed to evaluate soldier mobility and portability issues.
- A computerized firing range to examine soldier weapon performance issues (see Fig. 1).
- A state-of-the-art acoustics laboratory to study auditory processing issues.
- A vision laboratory designed for the study of night vision devices.
- A hostile environment simulator capable of reproducing much of the audible, visible, and tactile stimulation experienced in combat.
- State-of-the-art computer systems that support sophisticated human performance and human figure models (see Fig. 2).

In addition, HRED researchers have access to the instrumented test courses and firing ranges of the Army's Test and Evaluation Command and ARL's ballistic and survivability/lethality testing facilities at Aberdeen.

HRED currently has 131 professionals divided almost evenly between psychologists and engineers. Fifty nine percent of the staff have graduate degrees in their fields. While HRED is centered at Aberdeen Proving Ground, almost half of HRED's 200 military and civilian personnel are located at 20 sites with combat developers or material developers and have unique access to advanced military equip-

Continued on page 10

Figure 3. Soldier traversing navigation course at Aberdeen Proving Ground wearing experimental helmet-mounted display.

ment and highly trained troops.

Current Projects

Command and Control (C2) Task and Workload Modeling. The Army C2 community is concerned with how new information technology and organizational changes projected for tomorrow's digital battlefield will impact soldier tasks and workload. To address this concern, HRED is modeling soldier performance using current and future equipment and organizations. The current work is centered on developing and validating task, workload, and information flow models of the maneuver battalion command posts. To date, three maneuver battalion Tactical Operations Centers configurations have been modeled representing current and future Command and Control Vehicle operations.

Soldier Performance With Helmet-Mounted Displays. This research is designed to quantify the impact of helmet-mounted displays and alternative display technologies and techniques on the performance of the dismounted soldier (see Fig. 3). Task times and errors are gathered during the execution of tightly scripted tactical scenarios, along with measures of cognitive performance, workload, and stress. The data are used to refine and validate a Task-Event Flow and Workload Model that examines the effects of new and emerging display technologies on both individual soldier and higher unit performance. The data obtained during these experiments and the model that evolves will provide guidance in the selection and design of display technology that maximizes the performance of the 21st century land warrior.

Improved Performance Research Integration Tools (IMPRINT). This is a suite of PC Windows-based soldier system analysis tools for evaluating soldier and unit performance, estimating life-cycle cost implications of concept and system design choices, and assessing battlefield effectiveness. The results can be used in technology assessments, operational test and evaluation, or as links in distributed interactive simulation and virtual prototypes. The current development effort is providing improved and streamlined analysis capabilities, common access databases for greater flexibility, and more options for increased modeling power.

Mathematical Model of the Ear. HRED has developed a mathematical model consisting of a system of coupled nonlinear differential equations or, alternatively, a network of electro-acoustic elements that maintain a conformity with the ear's physiology (see Fig. 4). Free field sound pressures drive the model, and values representing displacements,pressures, velocities, etc., can be calculated for structures as far along

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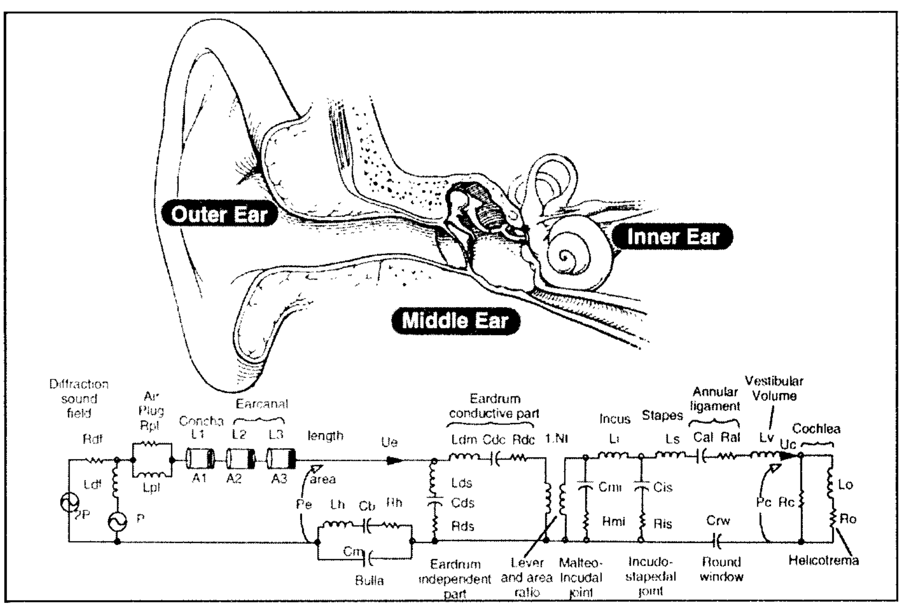

Figure 4. Electro-acoustic model of the ear.

Air Force Research Laboratory Human Engineering Division Colloquium Series

Designing for Physical, Cognitive, and Social Attributes in HCI

Gavriel Salvendy

Editor's note: Following is a synopsis of a presentation by Gavriel Salvendy, Ph.D., NEC Professor of Industrial Engineering, Purdue University, West Lafayette, Indiana, as the fourth speaker in the 1996 Armstrong Laboratory Human Engineering Division Colloquium Series: Human-Technology Integration. Please note that the Armstrong Laboratory in now part of the Air Force Research Laboratory, hence the change in title. This synopsis was prepared by Robert Mitman, Human Factors Engineer, formerly with CSERIAC and currently with General Motors, Inc. JAL

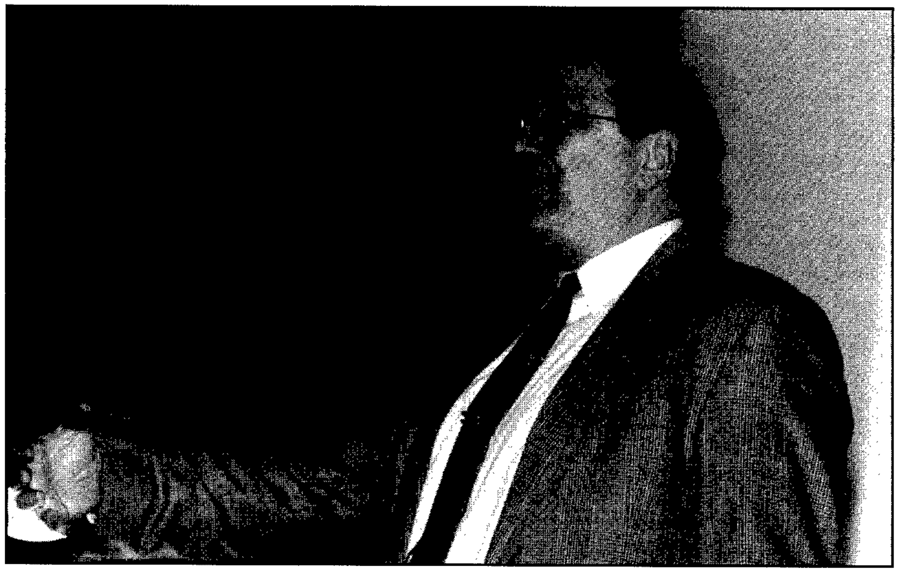

Figure 1. Gavriel Salvendy, Purdue University, West Lafayette, IN.

Dr. Gavriel Salvendy discussed his views and research findings promoting the design of human-computer interaction (HCI) systems that address the physical, cognitive, and social attributes of the user. His main objective was to present a broad picture of the opportunities and contributions that can be made to human systems through HCI.

To begin, Dr. Salvendy gave a perspective of HCI and its involvement in industry today. From a management perspective, he sees HCI as a way to increase quality, productivity, and overall efficiency of an organization. However, there are many human factors concerns in industry when considering HCI. For example, when the human is out of the system, the HCI system must consider what type of information is needed for the user to elicit knowledge. Only knowledge that is needed to make decisions should be embedded in the HCI knowledge system. A human-out-of-the-system HCI must also promote early diagnosis by providing correct information to support early and accurate detection. When considering human-in-the-system HCI, Dr. Salvendy stated that the design of a product which is useful and effective for the human to work with can be facilitated through the HCI. He stated that one area in particular, personnel selection and training in the medical, dental, and surgery industries, saw an 80% increase in quality and a 25% reduction in training time as a result of an effectively designed computer system.

In terms of research in HCI, Dr. Salvendy introduced findings from process research activities. He discussed the process of software development known as the "software factory," which challenges the past convention of producing software one item at a time. The software factory concept uses the same techniques as other large-scale product manufacturing industries that employ segmented development and mass assembly to simplify the process. Past research has found this concept to decrease employee training time and costs, increase speed by 7% - 10%, and result in an inherent quality-control system.

Another process affected by HCI is job design. Dr. Salvendy indicated that studies have found that 45% of the labor force working with computerized systems prefer fragmented job requirements. The majority of this group were older, less-educated employees who liked having simplified job requirements. The same study found that 45% of younger, educated employees liked a more enriched work environment, worked faster, and were more productive in this type of environment. Interaction with computers allows for job enrichment and job simplification in the same workplace due to the ability

Continued on page 12

to incorporate different software applications for both older and younger employees. This type of situation leads to higher job satisfaction, more productivity, and fewer errors through both job simplification and job enrichment.

Dr. Salvendy then cited findings from an HCI physical study that looked at the issue of carpal tunnel syndrome (CTS) with using computer systems. This research specifically investigated predictive issues related to CTS and found that posture and duration both have an effect over the long term. Results indicated that the degree of backward angle of the trunk inclination during seating is an important variable. A 24-degree incline backward resulted in a .1 probability of CTS, while a 1-degree incline or almost straight posture resulted in a .6 probability of CTS. When considering duration, regardless of any other variables, the probability of developing CTS is about .9 when working with a computer system three and a half hours a day. The probability decreased to .3 when only working one quarter of an hour per day. He stated that knowing the key variables that contribute to the CTS phenomena and predicting its occurrence is a much more prudent approach than simply measuring its existence.

When designing interfaces and considering how people represent information in their minds, Dr. Salvendy stated that one of the major problems is that all people are different in size, shape, and mental attitude. A designer cannot create a system which is suitable to everyone; one must concentrate on designing adaptive systems. Salvendy's dream is that one day systems will be so adaptive that when a credit-card size chip embedded with an individual's characteristics is plugged into a computer, it will activate an interface in the mode most appropriate to the individual. It has been demonstrated that adaptivity pays off in terms of user satisfaction and performance. Preliminary results of one study have shown that matching the "personality" of the software to match the "personality" of the user decreased error rate by 25% and increased satisfaction by 40%.

Adaptive interfaces could also address interface concerns when considering people from different cultures. Dr. Salvendy discussed results from a psychological study that identified conflicting interface representations between American and Chinese cultures. Four interface issues were found to be different between the two cultures:

- Functional relationships related to icon meanings and other interface functionality were different between Americans and Chinese;
- Concrete knowledge representation is preferred by the Chinese and results in a 9% increase in performance when compared to an abstract representation preferred by Americans;
- Information structure supports the need for software to match the cognitive structure of the culture of people using the software interface. Results indicated that the Chinese like thematic structure and had 13% faster performance and 59% fewer errors when compared to the American-preferred functional information structure;
- Presentation mode for the interface components is very significant in the usability of the interface between the two cultures. The Chinese use pictorial presentations 28% faster than alphanumeric, and Americans use alphanumeric presentation 32% faster and 93% more accurately than pictorial..

Dr. Salvendy concluded his presentation by discussing the design of HCI for information systems. He stated that when considering who should be responsible for what information and where the decisions should occur within the organization, two questions need to be asked. First, if the interface is to be menu-based, should it employ a hierarchical or parallel menu design? Second, is it better to employ automated command control decision making or to empower the employees and allow them to make decisions locally at their HCI workstations? Research results have found that local decision making leads to improved quality, speed, and error rate. These results have also been found when using a menu-based interface. ●

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as the basilar membrane, which is the primary site of damage from high intensity impulse noise. The model includes a nonlinear middle ear at high intensities and calculates hazards within the cochlea, based on the mechanical stress at the level of the basilar membrane. For intense sounds, the model ranks hazards appropriately and suggests that damage is the result of factors not previously accounted for and that no standard analytical technique could succeed. It also suggests novel means for ameliorating hazard. Advantages of the model are that it suggests strategies for reducing hazard without penalizing weapon performance and it provides a basis for a new international standard for impulse noise exposure.

HRED takes pride in its numerous contributions to the US Army materiel development cycle during its 46-year history. The Directorate looks forward to continuing its significant role in human performance research and human factors integration. ●

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Doug Tyrol is Assistant Director for Technology, Human Research and Engineering Directorate, US Army Research Laboratory, Aberdeen Proving Ground, MD.

Examining the Concept of Total Fidelity Flight Simulation

Ken M. Klauer

An Observation

An advertisement for flight simulator visual display systems in a major defense industry periodical emphatically stated that "transfer of training approaches 100%" when using their system. The manufacturer attributes the impressive performance of its visual system to the fact that the "components are fully correlated." Aside from this puzzling assertion, this manufacturer, like many others, appears to suggest that the key to high transfer of training depends solely on improvements in simulation technology.

The design of flight simulators has taken a technology-driven tack under the assumption that high physical fidelity is required for skill transfer to the parent aircraft. A corollary to this assumption is that "total fidelity" will bring about even higher training transfer values. However, a recent Air Force document, *New World Vistas, Air and Space Power for the 21st Century*, warns that total fidelity is very expensive and may not be necessary. A National Training Systems Association study, *Training 2000*, predicts a shift in emphasis from large-scale simulators to smaller, deployable, multi-purpose flight simulators. These two reports suggest a migration to lower-fidelity simulators within the DoD and underscores the need for a shift in the conception and design of simulators.

The total-fidelity mantra has been voiced for a long time in the training and simulation community, in part because of its significant intuitive appeal–the closer a flight simulator corresponds to the actual flight environment (i.e., high physical fidelity), the more skills will transfer to the aircraft. However, many organizations are beginning to question the economic realities of total-fidelity simulations in the context of current DoD budget cuts. Small increases in fidelity are expensive and difficult, if not impossible, to measure in regard to their impact on training.

Total Fidelity - A Flawed Concept

Consideration of the major premises of the total-fidelity concept reveals that it is fundamentally flawed. This premise is that aspects of the actual flight environment can be described for implementation in the synthetic world of the flight simulator. The physical aspect of the aircraft (e.g., avionics, cockpit layout, control loadings, etc.) can be described and modeled in great detail. However, we do not yet possess a language to describe the richness of the visual scene viewed by the pilot. This failure is evident in simulator design by the persistent use of physical display system parameters such as bandwidth and resolution as a measure of its contribution to training. These parameters provide little insight into the higher-order visual information needed by the pilot for control and the acquisition of flight skills.

Motion cues also pose similar difficulties. While they can be described by physical laws, we cannot yet describe the pilot's *perception* of them. For example, simulator motion cues are currently described in terms of the number of degrees of freedom, and the amplitude and acceleration possible in each dimension. It is difficult to relate motion cues expressed in physical engineering terms to their functional significance in the performance of specific flight tasks. For example, a roll motion cue accompanying a control input has a very different meaning to the pilot than a roll cue resulting from turbulence or some other external event. Perhaps vestibular cues are not needed in response to a pilot-initiated movement of the aircraft; the tactile cues provided by the controls in conjunction with a wide field-of-view visual system might provide ample feedback to maintain control and acquire task-related skills. Conversely, movement of the aircraft that is not initiated by the pilot may require vestibular cues to alert the pilot. Note that the physical motion of the simulator platform may be identical in each case, but the motion cues are redefined in terms of the pilot's perceptual requirements.

Recognizing the different perceptual requirements of pilot-initiated movements of the aircraft and movements resulting from external forces is the start of a rudimentary language of simulator motion cuing. However, a complete descriptive language of the simulator cuing requires further understanding of higher-order human perceptual processes. The behavioral sciences are relatively well versed in the lower-order *sensory* processes, but almost nothing is known about higher-order *perceptual* processes. For example, the relationship between luminance levels and acuity is a lawful and well-understood lower-order phenomenon of vision; acuity decreases with luminance. However, the influence of high-order perceptual relationships between elements of the

visual scene, such as optical flow, are just beginning to be investigated.

Models of the human vestibular system have been used in an attempt to describe the pilot's experience of motion, but these models only validate the capability of the simulator to elicit the lower-order vestibular sensory information experienced in flight. The lower-order sensory information provided by the pilot's vestibular organs is only a portion of the information needed for the perception of motion.

The high-fidelity concept constrains simulator design by focusing on the salient cues in simulation. Many other cues are needed to synthesize the total perceptual experience of flight, many of which are not readily perceived by the pilot. Sensations of changing air pressure may signal changes in altitude or augment other visual and motion cues. Likewise, aural representations of the engine and slipstream in synergism with visual and vestibular cues may be a much more potent signal to changes in attitude and acceleration than each cue presented alone. Aural cues have been added to aircraft simulations, but little effort has been made to assess their realism or coordinate them with other cues or flight tasks. Flight tasks must be examined in detail to determine their true perceptual requirements.

Simulator Validity: A Pragmatic Concept

The emerging concept of simulator validity stresses the degree to which a simulator facilitates the transfer of skills to the aircraft and may provide better insight into simulator design. In contrast, the total-fidelity concept stresses the degree to which the major aspects of the simulation independently correspond to the actual flight environment (e.g., motion, visuals). Because it is assumed that high training transfer will result when this condition is met, the specific identification of cues providing the greatest training value is not formally emphasized. However, many cues in the flight environment are redundant, and considerable savings may be realized by replicating only those cues needed to acquire task skills.

The validity concept emphasizes the higher-order cue relationships perceived by the pilot rather than pilot performance. The temporal phase difference between vestibular cues is an example of a higher-order cue relationship or emergent cue structure that may be altered in the simulator. However, the presentation of these cues occurs simultaneously in the aircraft; an initial change in one cue must be accompanied by a change in the other. Why then is the phase relationship between visual and motion cues often the subject of hot debate and subsequently altered in the simulator? One reason lies in the emphasis on pilot performance in the simulator over skill acquistion. Skill acquistion is the process of learning to identify cues structures that support skilled performance. In the case of flight simulation, these cue structures should ideally correspond to those encountered in flight. However, the high-fidelity concept has not emphasized the study of these higher-order cue relationships to direct design, so pilot performance in the simulator is used as a rough guide to the efficacy of the cue structures available to the pilot. Unfortunately, the cue structures supporting high performance in the simulator may be far different from those present in the aircraft. The phase relationships between visual and motion cues are often "tweaked" to improve simulator performance with little thought as to how this may impact skill acquisition.

The validity concept demands clear training goals for the simulator. The validity concept considers the simulator's training potential for specific flight tasks and pilot experience levels relative to the cue structure presented to the pilot. For example, experienced pilots use many more subtle cues than novices in the performance of a given task.

Implementation of the Validity Concept

To exploit the concept of simulator validity, new descriptions of the tasks and cues presented to the pilot are needed for initial simulator development. Detailed task analyses associating pilot actions with task-relevant cues are needed (see Brown, Cardullo, McMillan, Riccio, & Sinacori, [1991] for an excellent example). Often, even standard normative process-based task analyses do not exist for many aircraft, or they are out of date. A descriptive language of simulator cuing is also needed to communicate the perceptual requirements of flight tasks to simulator designers.

Formalized procedures for assessing simulator validity are also needed. The "backward" transfer-of-training methodology is an example of such a procedure (Cross, 1992). The backward transfer-of-training methodology uses experienced pilots who have not flown the simulator in question. Initial pilot performance and errors made in the simulator are noted. If performance is significantly lower in the simulator and more procedural errors are made, then the validity of the simulator is low. It is important to assess only the initial performance in the simulator because experienced pilots are able to rapidly adjust to suboptimal cue structures.

A closer analysis of pilot errors and performance decrements in the simulator will suggest absent or inadequate cue structures. Recently developed cognitive task analysis methods are ideally suited to this aspect of the backward transfer-of-training methodology (see *Gateway*, Vol. VII, No. 4, for a discussion of cognitive task analysis methods). The backward transfer of training method also provides a context in which subtle, perhaps unconsciously perceived cues are made salient (i.e., not missing something until it is not there).

A traditional forward transfer-of-training design associated with the total fidelity concept assesses the training

potential of the simulator by simply measuring the time taken in the simulator to learn a task in relation to time taken in the aircraft to learn the same task. However, this methodology does not suggest potential causes of poor performance unless pilot opinions are elicited. Pilots' opinions on the cues presented in the simulator are formally recognized as a valuable asset when the backward transfer-of-training methodology is adopted.

Summary

Any advancements in the technology and hardware of human-in-the-loop simulation must parallel insights into higher-order perceptual processes to improve training. The National Research Council (Jones, Hennessy, & Deutsch, 1985) noted that examination of the research literature and recommendations of science advisory groups for 30 years previous to their report revealed that the simulator problems identified are common to most simulation contexts, have been identified repeatedly, and have persisted. A CSERIAC review of the literature since 1985 revealed similar findings. These problems have remained because solutions depend on a better understanding of the higher-order perceptual processes. The best insight to higher-order perceptual processes applicable to the flight environment is the opinion of experienced pilots. The backward transfer-of-training methodology encourages these opinions to pinpoint inaccurate or absent cue structures that retard skill acquisition in the simulator. ●

Ken Klauer, formerly a Human Factors Analyst with CSERIAC, currently works for Battelle Memorial Institute, Seattle, WA.

Dear CSERIAC...

To show the diversity of support that CSERIAC provides, this column contains a sampling of some of the more interesting questions asked of CSERIAC. In response to these questions, CSERIAC conducts literature and reference searches, and, in some cases, consults with subject area experts. These questions have been compiled by Debra Urzi, Human Factors Engineer. If you would like to comment on any of these questions or issues related to them, please write to "Dear CSERIAC" at the address found on the back cover of *Gateway* or email Debra at urzi@cpo.al.wpafb.af.mil

■ A member of the US Air Force, working temporarily for the FAA, asked CSERIAC to determine how low the ambient illumination level of a workstation could be before a backlit keyboard would be recommended.

■ A representative of a midwest computer systems company requested information about reach, especially for individuals in wheelchairs.

■ Information pertaining to the human factors issues associated with the design of ground-based command and control facilities, specifically those associated with remote automated maintenance facilities, was requested by a defense contractor.

■ A public relations firm requested information regarding women's preferences for ergonomically designed products.

■ A research company contacted CSERIAC to request information discussing holster (or gun belt) weight and subsequent back injury.

■ Information regarding the effects of 12-hour shifts on worker stress, fatigue, and performance was sought by a representative of the US Air Force.

■ CSERIAC was asked by the US Air Force to provide graphic depiction of what happens to crew performance, particularly at the 14-16 hour duty point, and at crew members' circadian rhythm "low" that equates to about 0300 hours for individuals accustomed to arising at 0600 for a standard day of work.

■ A US defense contractor contacted CSERIAC requesting information pertaining to materials that would not transmit heat as readily as metal.

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CREW SYSTEM ERGONOMICS INFORMATION ANALYSIS CENTER:

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- DESIGNING FOR PHYSICAL, COGNITIVE, AND SOCIAL ATTRIBUTES IN HCI
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CSERIAC PRODUCTS AND SERVICES

CSERIAC's objective is to acquire, analyze, and disseminate timely information on crew system ergonomics (CSE). The domain of CSE includes scientific and technical knowledge and data concerning human characteristics, abilities, limitations, physiological needs, performance, body dimensions, biomechanical dynamics, strength, and tolerances. It also encompasses engineering and design data concerning equipment intended to be used, operated, or controlled by crew members.

CSERIAC's principal products and services include:

- technical advice and assistance;
- customized responses to bibliographic inquiries;
- written reviews and analyses in the form of state-of-the-art reports and technology assessments;
- reference resources such as handbooks and data books.

Within its established scope, CSERIAC also:

- organizes and conducts workshops, conferences, symposia, and short courses;
- manages the transfer of technological products between developers and users;
- performs special studies or tasks.

Services are provided on a cost-recovery basis. An initial inquiry to determine available data can be accommodated at no charge. Special tasks require approval by the Government Technical Manager.

To obtain further information or request services, contact:

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